

Hardware Improvements for the APS Storage Ring

January 20th 2003

Louis Emery

Presented to ASD

Priority

- This year's:
 - Most technical issues solved.
 - Costs may not be known.
- Next year
 - May need to do some R&D, some aspects unknown
 - No budget known
- Much later
 - More difficult projects.

Improvements Not Covered

- Software, i.e. Automated injection tuning
- Procedures, i.e. Calibrating all new quadrupole converters.

Information Presented on Improvements

- Benefits.
- What progress as been done so far.
- New components.
- Specifications.
- What still needs to be done.
- What are the unknown aspects

Upgrade of the BTS BPMs

- Purpose:
 - Reduced electrical noise from 1500 μm to 15 μm .
 - Help diagnose injection problems.
- Status: Finished this shutdown
- New components: Electronics.
- Specifications: Noise level at least as good as SR bpms.

Replace the Ceramic Kicker Chambers

- Purpose:
 - Make bellows assembly independent from ceramic.
 - Reduce injection bump mismatch with chambers of matched resistivity.
- Status: Ceramic chambers delivered and measured. Best group of 4 to be selected after comparing measured magnetic field waveforms.
- New components: Ceramic chambers, bellow assemblies.

Replace the Ceramic Kicker Chambers (cont'd)

- Specifications: Noise level at least as good as SR bpms.
- R&D required: Develop method to adjust the effective resistance.
- Unknown aspects: None

New Vertical Scrapers

- Purpose:
 - New design to reduce HOM heating.
 - Improve collimation properties.
- Status: Design stage.
- New components: Two scraper assemblies.

New Vertical Scrapers (cont'd)

- Specifications: New geometry to reduce HOM heating by a large factor, not determined yet.
- R&D required: Calculate impendance with MAFIA, optimize thickness of W material.
- Unknown aspects: Effectiveness as collimator, which is not easily simulated.

Stabilize Booster Extraction Septum Magnet PS

- Purpose:
 - Reduce trajectory jitter (2.5 mm p-to-p) which makes the booster beamsize ($\sigma=1.5$ mm) effectively larger.
 - Applicable to SR septum magnets.
- Status: ES performed test where external regulator was removed and internal regulation of new HV supply was used. The low amplitude first pulse was eliminated.
- New components: HV PS, modified circuit.

Stabilize Booster Extraction Septum Magnet PS (cont'd)

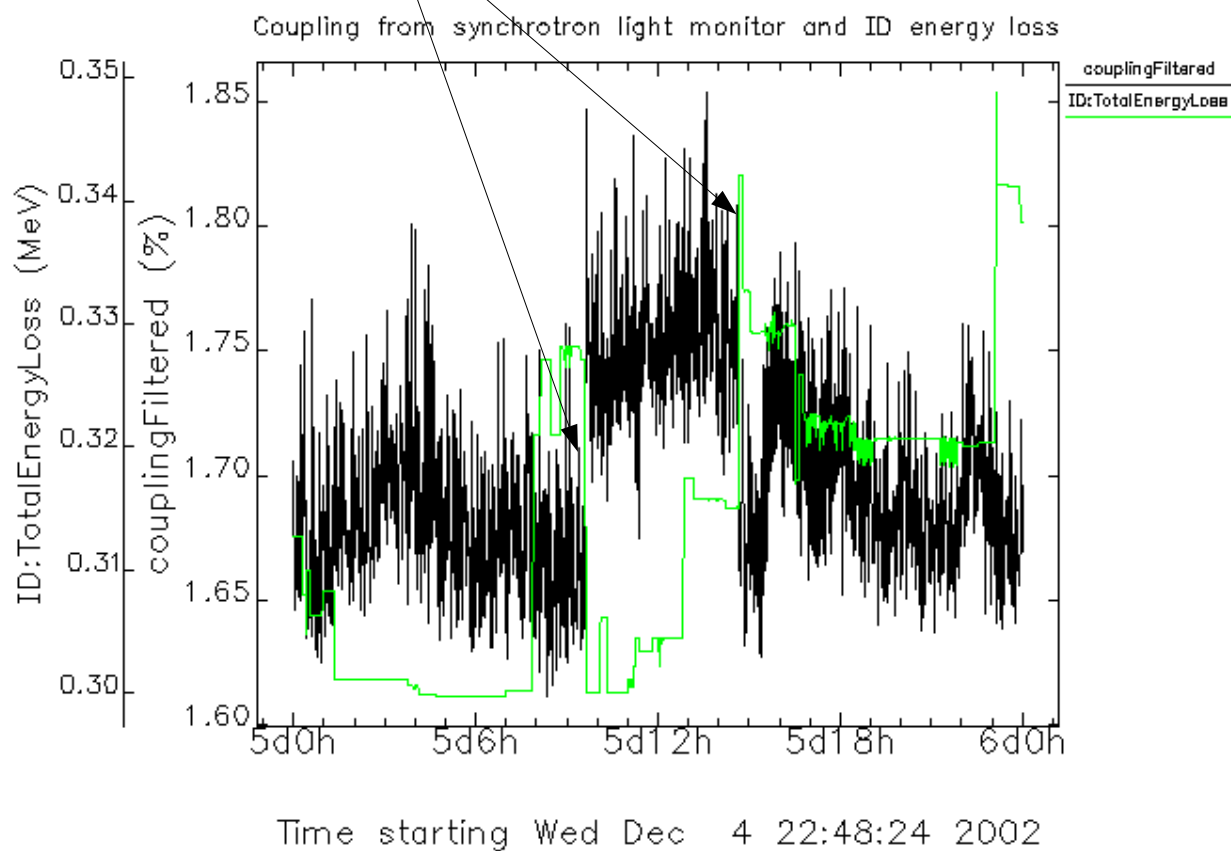
- Specifications: Stability of 1 part in 1500 for all pulses.
- R&D required: Circuit modification. Need beam studies to check.
- Unknown aspects: None.

Skew Quadrupoles at IDs

- Purpose:
 - Do feedforward on gap value to correct the skew quadrupole magnetic field perturbation.
 - May be used for global correction as well.
- Status: Just an idea.
- New components: One skew quadrupole per ID.
Could make copy of skew quads in ID4-CPU.

Skew Quadrupoles at IDs (cont'd)

ID changes that affect the coupling



Skew Quadrupoles at IDs (cont'd)

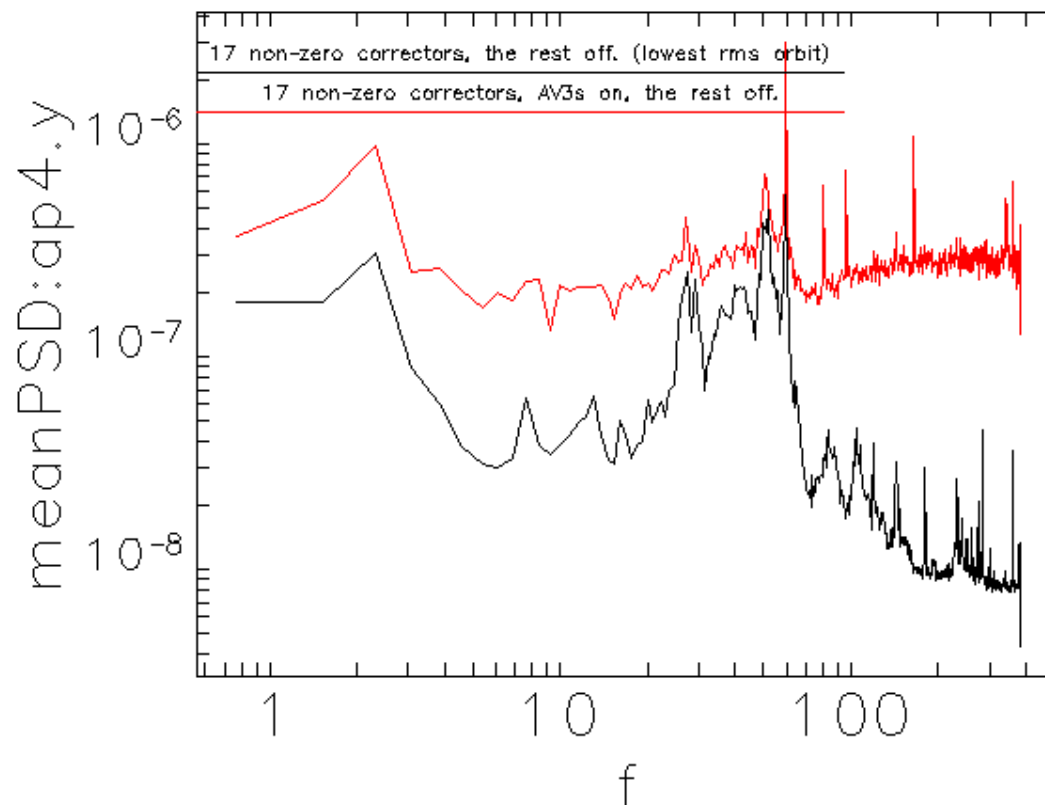
- Specifications: Maximum field not determined yet.
- R&D required: Construction of skew quadrupole magnets.
- Unknown aspects: No available space in straight section

Corrector Regulation Improvement

- Purpose: Reduce RMS orbit motion.
- Status: Orbit motion spectrum was taken in August 2002 under different running conditions. 38 correctors with steel VC has been characterized.
- New components: 76 regulators at first, then maybe the rest.

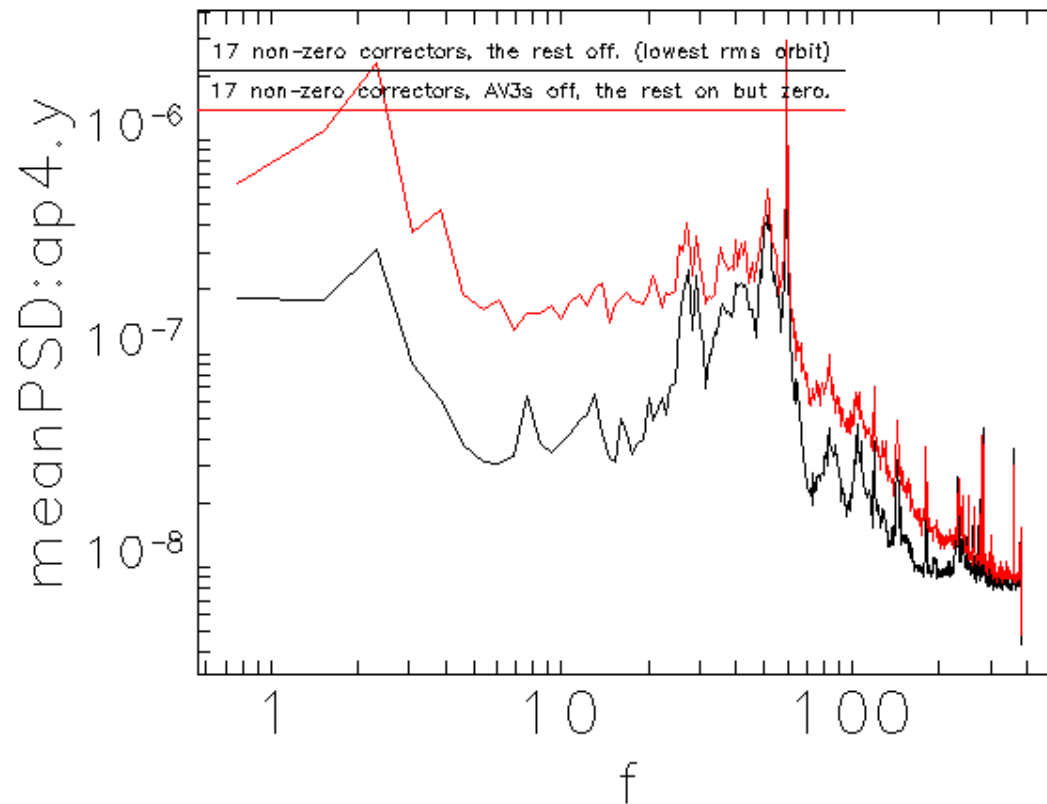
Corrector Regulation Improvement (cont'd)

Effect of 38 "fast" correctors:



Corrector Regulation Improvement (cont'd)

Effect of 262 "slow" correctors:



Corrector Regulation Improvement (cont'd)

- Specifications: Desired output spectrum not determined yet.
- R&D required: Develop regulators.
- Unknown aspects: Whether the regulators with AI chambers need improvement. (The AI VC already attenuate high-frequency noise)

Kicker Pulse Output History

- Purpose:
 - Post-beam dump analysis of events.
- Status: Just an idea. Several other systems have histories: bpm, correctors, video data of beam images.
- New components: None.

Kicker Pulse Output History (cont'd)

- Specifications: Record the kicker output at 0.5 s intervals with time stamp.
- R&D required: None.
- Unknown aspects: None.

Next Year's Improvements

Longer Straight Section. Phase 1.

- Purpose: Increase usable length of straight section from 5.0 m to 7.6 m to add a third undulator.
 - Remove H1/V1 and Q1 magnets.
- Status: Users are expecting this to happen. Studies guaranteed the feasibility of the optics in low-emittance and high-emittance, though lifetime is reduced somewhat.
- New components: ID VC extrusion, SR VC extrusion, transition box, new girders #1 and #5.

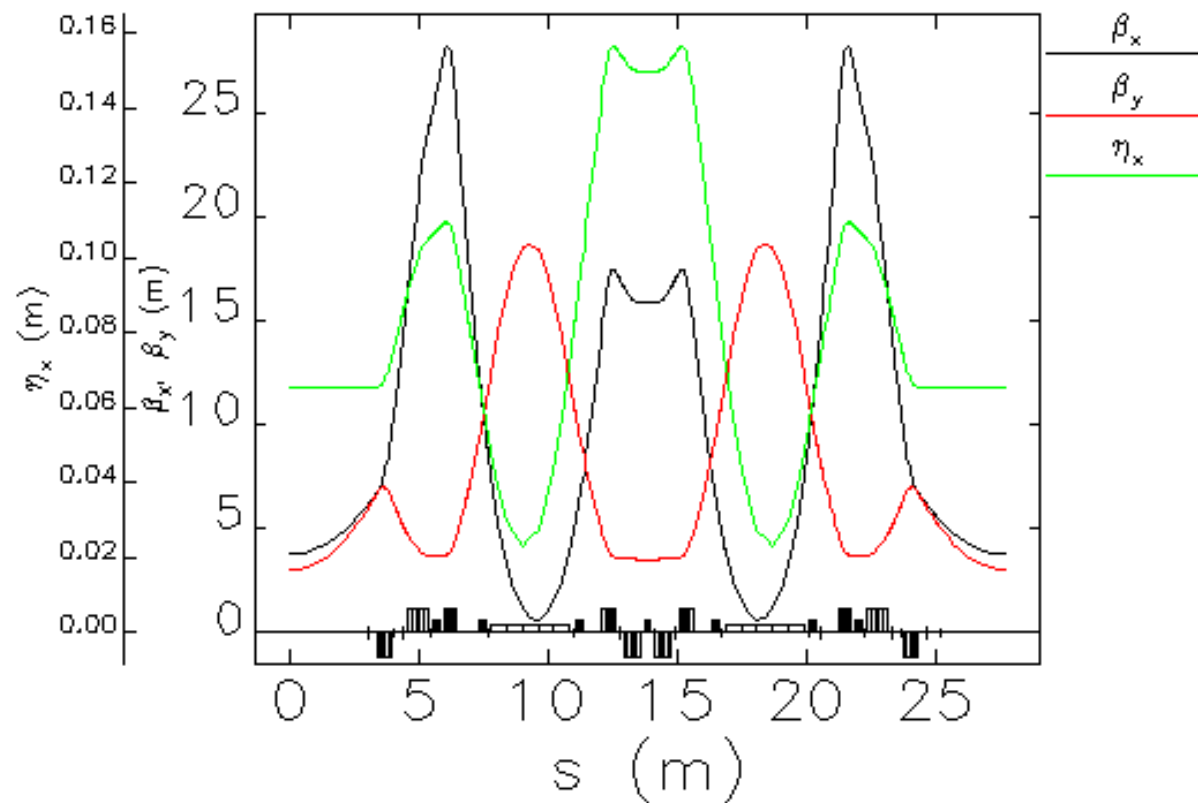
Longer Straight Section. Phase 1. (cont'd)

- Specifications: Fits three undulators. No strong reduction of lifetime. Minimum vertical aperture is not known, probably not 5 mm.
- R&D required: Synchrotron radiation masking should be re-examined. Studies on optics matching of reduced flexibility.
- Unknown aspects: None.

Dipole with Gradient

- Purpose: Lower emittance cell.
 - $\varepsilon_x = 1.2$ nm-rad and effective $\varepsilon_x = 1.8$ nm-rad.
 - Necessary gradient is -0.17 1/m², which is very high.
 - Choice of canted poles or new windings on existing pole face.
- Status: Just an idea.
- New components: Either new dipoles, or new coil windings on pole face. Probably new SR curved extrusion in both cases. Stronger sextupoles.

Dipole with Gradient (cont'd)



Twiss parameters for sector1

Dipole with Gradient (cont'd)

- Specifications: Angle of canted pole face, current of windings (not calculated). Alignment of dipole.
- R&D required: Feasibility of winding idea (i.e. massive cooling for windings). Feasibility of canted pole face. Nonlinear analysis of cell.
- Unknown aspects: Which approach is easier. Perhaps we are satisfied with intermediate lower emittance obtained with rf frequency shift of +500 Hz.

Kicker PS Adjustments

- Purpose:
 - Make identical normalized waveforms for all amplitudes.
 - Towards transparent injection.
- Status: Kicker PS have an amplitude dependence, especially in the tail.
- New components: Unknown.

Kicker PS Adjustments (cont'd)

- Specifications: Normalized waveforms to be 1% of average.
- R&D required: Unknown
- Unknown aspects: Perhaps specification can be relaxed with secondary kickers applying corrective kick.

Waveform-Programmable Kicker

- Purpose: Correct betatron oscillation of stored bunches during injection. Program an actuator with the same waveform every injection event.
- Status: Just an idea.
- New components: Two kicker striplines or magnets. Two amplifiers. Waveform generators.

Waveform-Programmable Kicker (cont'd)

- Specifications: Bandwidth of about 10 MHz, strength about 5% that of injection kicker.
- R&D required: Kicker magnet.
- Unknown aspects: Could a transverse feedback system accomplish the same thing? Note that a feedback system corrects over many turns while we want the (large) correction to occur in one turn.

Vertical Wiggler

- Purpose: Adjusts vertical emittance for lifetime.
 - Present method of adjusting vertical emittance compromises injection efficiency.
- Status: Just an idea.
- New components: Electromagnetic wiggler magnet, special absorber for strong radiation.

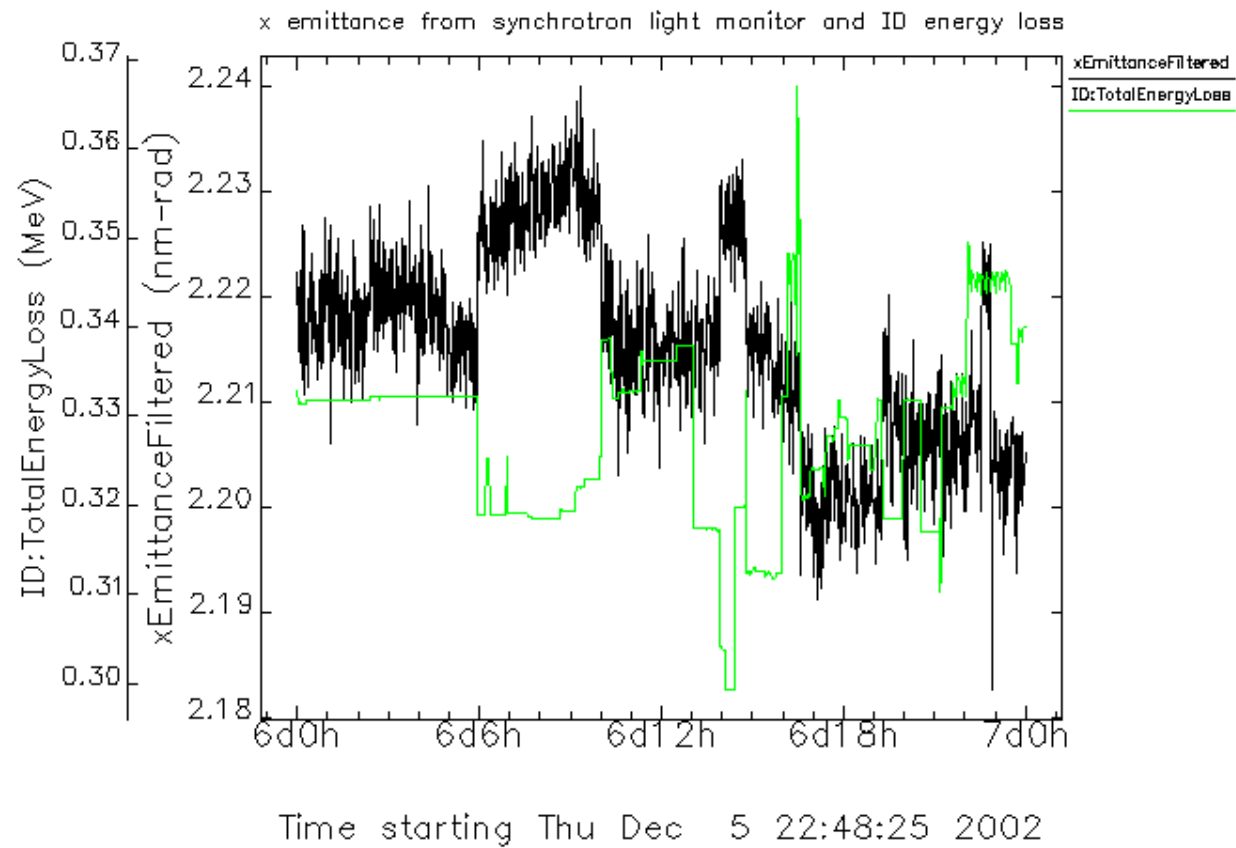
Vertical Wiggler (cont'd)

- Specifications: Horizontal aperture of ± 20 mm. Zero horizontal dispersion. Long period to generate vertical dispersion. Required strength unknown.
- R&D required: Wiggler and radiation absorber.
- Unknown aspects: Need a straight section from some sector. Future requirements for vertical emittance.

Horizontal Wiggler

- Purpose: Compensate the variation of emittance due to ID gap ramps through damping adjustment.
- Status: Just an idea.
- New components: Electromagnetic wiggler, absorber for strong radiation.

Horizontal Wiggler (cont'd)



Horizontal Wiggler (cont'd)

- Specifications: Need zero dispersion straight section. Strength unknown but can be derived from User run history.
- R&D required: Radiation absorber.
- Unknown aspects: Need a straight section.

BPM Memory/Scanner Upgrade

- Purpose: Produce simultaneous averages from various digital filters for turn-by-turn history, orbit correction, glitch logging, long-term data logging.
- Status: Ideas developed by DIA group and Lenkszus. Low priority. Project stalled?
- New components: Electronics.

BPM Memory/Scanner Upgrade (cont'd)

- Specifications: Simultaneous filters.
- R&D required: Unknown
- Unknown aspects: None.

HOM dampers for SR Extrusions

- Purpose: To remove random error in vertical bpm readbacks.
- Status: Ideas developed by DIA group. Dampers were inserted in one VC, but has not reduced the effect of the HOM by the expected factor. Project stalled.
- New components: HOM dampers.

HOM dampers for SR Extrusions (cont'd)

- Specifications: Reduce HOM by orders of magnitude to reduce random error to $< 1 \mu\text{m}$.
- R&D required: Need more ideas.
- Unknown aspects: Many

SR Dipole PS Stability

- Purpose: Improve by large factor to improve bunch cleaning effectiveness, i.e. keep tunes constant. Also studies dependent on tune measurements would benefit.
- Status: ES group waiting for specifications. Present stability is 1 part in 20,000 in the spectrum range DC to 1 Hz.
- New components: Regulator.

SR Dipole PS Stability (cont'd)

- Specifications: To be determined, but probably 1 part in 65,000 is sufficient.
- R&D required: Regulator, could be assisted by NMR probe output.
- Unknown aspects: None

Transverse Feedback System

- Purpose: Stabilize single bunch motion with lower chromaticity setting. This would increase lifetime.
- Status: Just an idea. We already have striplines available for that purpose.
- New components: Electronics to process beam signal into correction signal. Amplifiers.

Transverse Feedback System (cont'd)

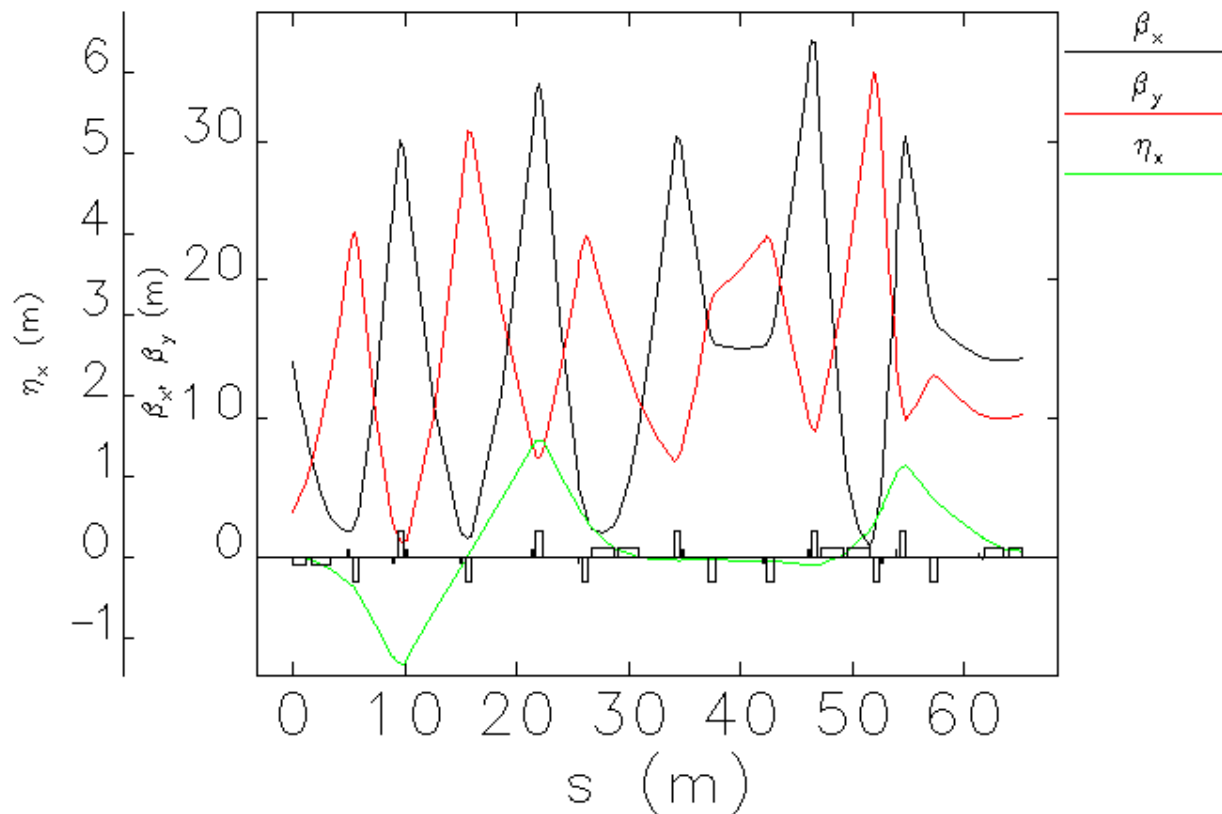
- Specifications: Bandwidth and power not known yet.
- R&D required: Many such system exists in other storage rings, so R&D may be minimal.
- Unknown aspects: Whether feeding back on centroid motion alone is sufficient in reducing the instabilities at operating bunch current.

Three-Screen Diagnostics System in BTS

- Purpose: Modify BTS line, and add three screens in order to make a emittance and beta function measurement.
- Status: Just an idea, but has been implemented in the linac after the bunch compressor.
- New components: 4-5 quadrupoles, high-resolution screens, perhaps CTR screens, more steering magnets.

Three-Screen Diagnostics System in BTS (cont'd)

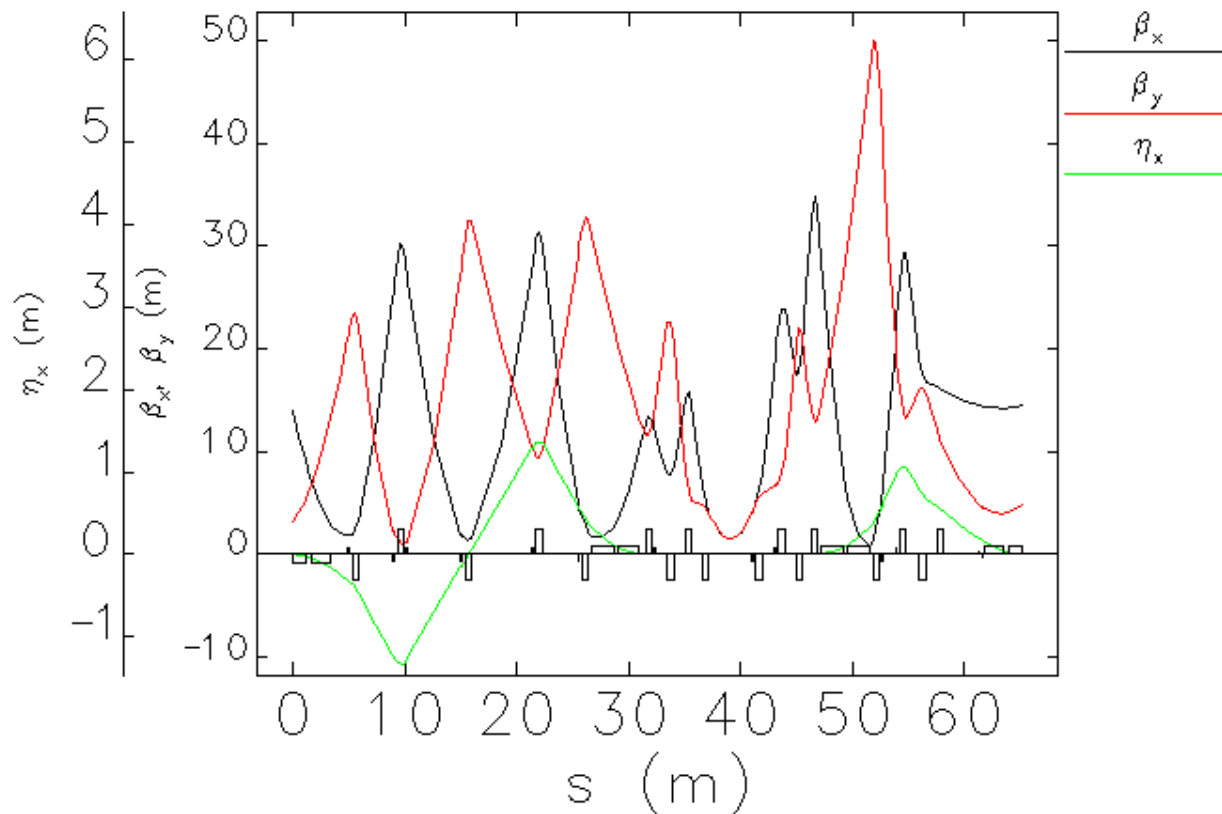
Original



Twiss parameters for bts

Three-Screen Diagnostics System in BTS (cont'd)

Three screens



Twiss parameters for btsM09

Three-Screen Diagnostics System in BTS (cont'd)

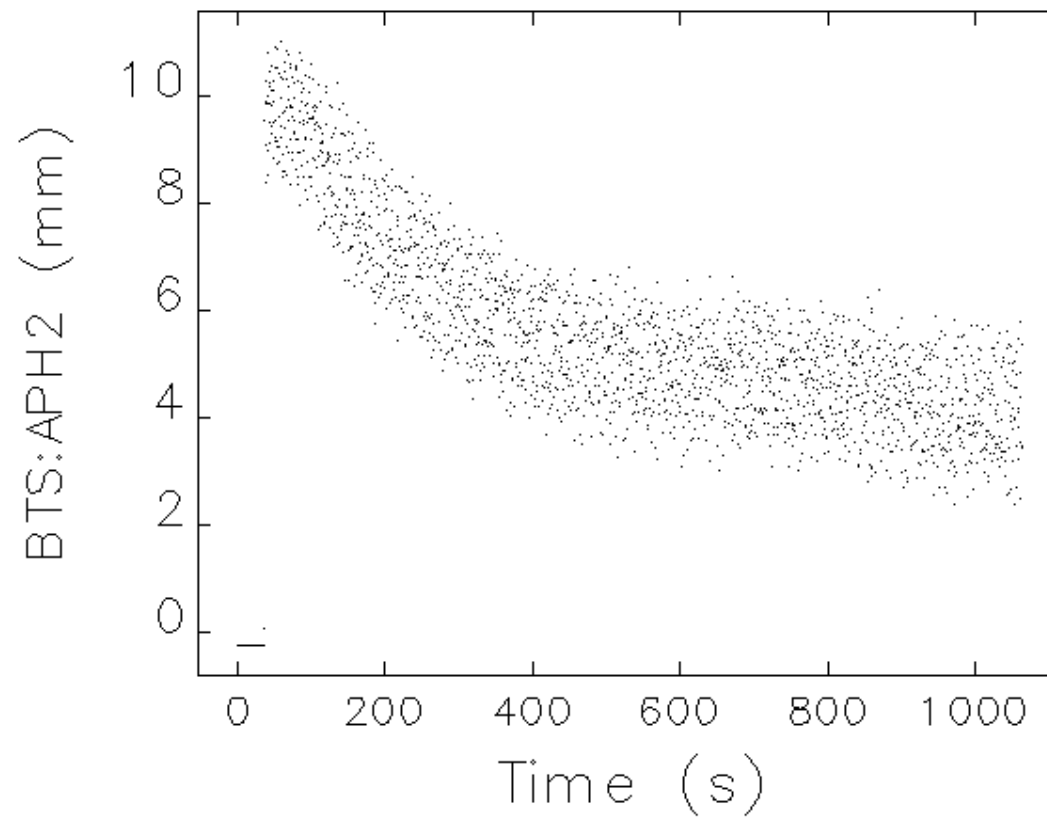
- Specifications: Resolution around 10 μm .
- R&D required: Optics matching.
- Unknown aspects: None.

Septum Regulation

- Purpose: Replace voltage regulation with current regulation to avoid doing feedforward on temperature or previous history of pulsing.
- Status: Voltage regulation causes a 10-minute transient on current output because of heating of coils.
- New components: More sophisticated regulator.

Septum Regulation (cont'd)

5-minute transient:



Septum Regulation (cont'd)

- Specifications: About 1 part in 1500.
- R&D required: Unknown
- Unknown aspects: How to coordinate this change with the improved HV stability mentioned earlier.

Longer-term Improvements

Longer Straight Section. Phase 2.

- Purpose: Increase usable length of straight section from 7.6 m to 10.6 m to add a fourth undulator.
 - Replace dipole with shorter magnet of increased strength. Move other magnets 1.5 m to make room.
- Status: Just an idea.
- New components: Dipole, ID VC extrusion, SR VC extrusion, transition box, new girders #1, #2, #4 and #5.

Longer Straight Section. Phase 2. (cont'd)

- Specifications: Fits four undulators. No strong reduction of lifetime. Minimum vertical aperture is not known, probably not 5 mm.
- R&D required: Same as phase 1 plus new dipole magnet.
- Unknown aspects: Can this be combined with dipole with gradient?

Higher-Conductivity ID VC

- Purpose: Reduce impedance of chambers. Coating Al VC with Cu will reduce resistance and impedance by factor 1.6, which is significant. Possible outcome is a reduction of chromaticity and increase lifetime.
- Status: Just an idea.
- New components: None. Reuse ID VCs.

Higher-Conductivity ID VC (cont'd)

- Specifications: Cu material. Thickness not determined yet. Sides not important.
- R&D required: Cu deposition.
- Unknown aspects: Vacuum issues.